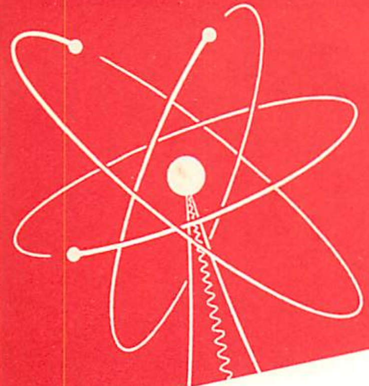

TUNER CIRCUITS

Lesson T2C-3A

DeVRY Technical Institute
4141 W. Belmont Ave., Chicago 41, Illinois
Formerly DeFOREST'S TRAINING, INC.

T2C-3A

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4141 Belmont Ave.

Chicago 41, Illinois

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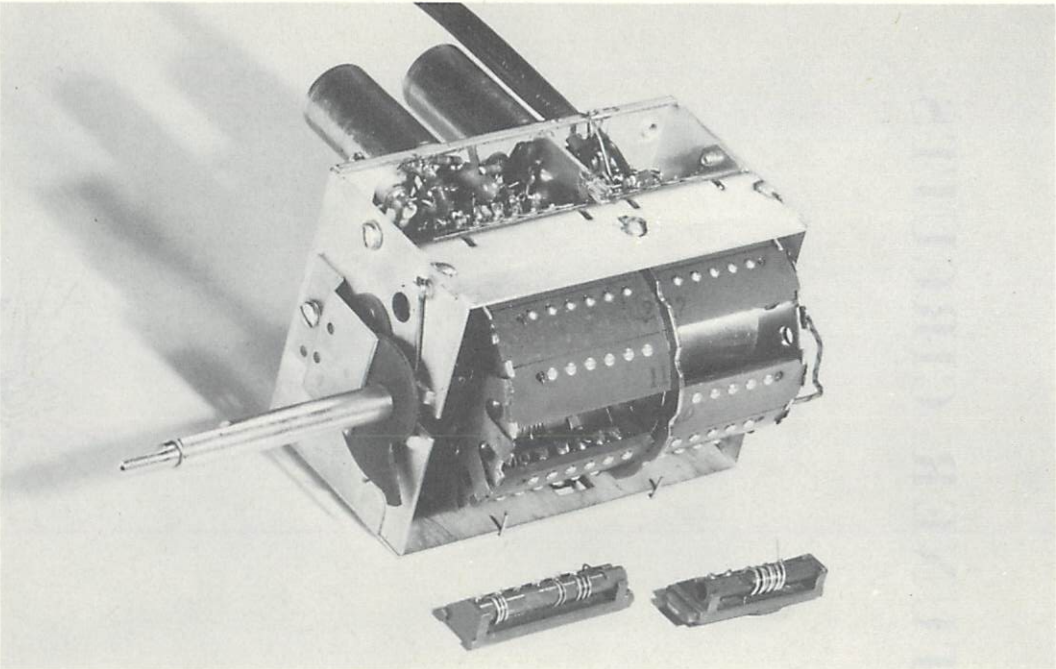

A turret tuner rotated to channel 2 position. At left is the r-f Mixer and Oscillator coil strip for channel 10, while at the right is the channel 11 r-f input transformer.
Courtesy Standard Coil Products Co.

TUNER CIRCUITS

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He who has health, has hope; and he who has hope, has everything.

—Arabian Proverb

TUNER CIRCUITS

The preceding lessons have described the modern television system with respect to basic requirements and FCC standards, and have given explanations of general transmitter and receiver arrangements used to reproduce satisfactory television broadcasts.

Starting with this lesson, we will describe the various sections of the television receiver and the actual circuitry which is involved. The explanations of the receiver sections will follow in the same sequence as the paths that the video and sound signals take from their input at the receiver all the way through to the picture tube and speaker output.

From the television receiver block diagrams of the previous lesson, you may recall the first section of the receiver in the signal path of the video and sound information is the tuner.

Because of the high frequencies that are employed for the carriers of the television signals, along with the required broad band coverage, careful consideration must be given to construction and also servicing of the tuner unit. In this lesson we will devote time to getting acquainted with some of the basic circuits used in the television tuners in addition to a description of the various characteristics and circuit requirements involved with high frequency, VHF-UHF, application. These basic conditions are of great importance to the competent television service technician.

THE BASIC TUNER ACTION

The object of the television tuner is to select the desired television channel and, in addition to amplifying the carriers, convert the carriers to an intermediate frequency range (r-f) for additional efficient amplification in the r-f sections of the receiver. Thus, the television tuner performs the same operation as any r-f Oscillator-Mixer section of a radio receiver.

As shown in the block diagram of Figure 1, the television tuner is divided into four general categories the functions of which are: (1) r-f amplifier, (2) mixer, (3) oscillator, and (4) channel selection. Of these, the first three are electron tube stages while the fourth is the arrangement for changing the values of L or C in the r-f, oscillator and mixer tuned circuits, to provide for channel selection.

Usually these circuits and arrangements are manufactured as a separate sub-assembly referred to as the tuner, and mounted as a complete unit on the main receiver chassis.

To tune an "all-wave" type of radio receiver over its frequency ranges, the input stages include some sort of a detent "band" switch arranged to connect different sets of coils into the active circuits. These bands may be named "Broadcast", "Police", "FM", and so on, or it may be calibrated directly in kilocycles or megacycles. With the switch set in a particular position, the controls fine tune the receiver across the indicated band.

Similar circuit arrangements are necessary in a television receiver, but each television broadcast station is allocated an entire six megacycle band known as a channel. At present, 82 channels, numbered consecutively from 2 to 83, are in use. Because of this arrangement, it is customary to refer to television stations by channel number instead of by call letters or carrier frequencies. Thus, the television receiver band selection positions are marked in channel numbers.

ELECTRON TUBE PROPERTIES

Capacitive Conditions

In Figure 2 is an equivalent tube diagram which shows the inter-electrode capacitance effect described in a previous lesson. At the high frequencies, such as VHF and UHF used in television, these capacitive qualities have a large effect. Therefore, they require extensive consideration in tuner circuits. Of course, the external stray capacitances of the tube stage existing between the tube socket connections, leads, etc., also become an important part of tuner circuitry.

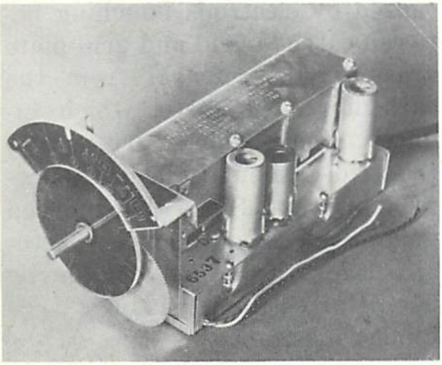
In addition to the capacitive effects mentioned, when a signal is applied to the tube, another effect makes its appearance, called *hot input capacitance.*

This hot input capacitance effect is a grid circuit condition caused by electrons bunching between cathode-grid and grid-plate areas in their travel from the cathode to the plate, which induces minute signal current into the grid element, called displacement current. Since this induced grid displacement current actually leads the signal voltage by 90°, it gives the effect of a large input capacitance.

An analysis of this condition finds that as an increasing quantity of electrons approach the grid, they repel other electrons already in it, causing them to move in a direction away from the grid through the external tube circuit around to the cathode. After the electrons pass the grid and are moving away from it toward the plate, the displaced electrons return back through the external circuit to their original position on the grid.

Thus, when a signal causes the grid to swing positive, there will be more plate current electrons approaching the grid from the cathode than going beyond it toward the plate and, when the grid swings negative, fewer electrons will be approaching the grid and more will be in the area beyond it going toward the plate.

The actual a-c grid displacement current is produced by the passing stream of electrons varying with the input signal voltage, e_g, which causes a more or less repelling action to the electrons on the grid, producing a final charge on the grid, Q_g. As shown in Figure 3, this makes the maximum grid charge, Q_g, in phase at any instant with the applied signal, e_g.



A television tuner of the continuous tuning type covering the VHF television channels and the FM stations. Three 7-pin miniature tubes for the r-f, mixer and oscillator circuits are under the shields. It uses a 72-ohm input transmission line.

However, the resulting repelling action itself, which causes displacement current, i_d, will be maximum when the electrons in transit are at their greatest rate of acceleration change. This occurs as Q_g goes through the zero axis as shown in the curve of Figure 3. Thus, the actual displacement current i_d leads Q_g by 90°. Since Q_g is in phase with the appplied e_g, the displacement current, i_d, also leads e_g, by 90° which is the equivalent of a capacitive effect on the applied signal.

These various inherent tube capacitances all play a part in the resonant frequency of the tuned circuits in the tuner, and also place an undesirable limit on the L-C ratio of those circuits that keeps circuit Q down, limiting the tuner gain for any given bandwidth.

Conductance

In electron tube operation at high frequencies, another tuner limiting condition is the conductance factor between the cathode and the grid, which is the inverse of resistance. A high tube input conductance factor is the equivalent of a low value cathode to grid resistor which actually parallels or shunts the grid tuned circuit and again lowers the circuit Q.

The tube input conductance is composed of two conditions: the **cold input conductance** and the

hot input conductance. The cold conductance is mainly the dielectric losses in the glass envelope, the insulating supports and the lead wires of the tube. The hot input conductance is caused by a shift in the previously described grid displacement current's 90° phase relationship to the input signal.

It is known that an electron has mass and, according to the laws of physics, any applied force, such as grid voltage, causes electron acceleration. Thus the electrons undergo a change in velocity which involves a certain lapse of time. The time it takes for the electrons to travel between elements inside a tube is referred to as **transit time.** This time for electron travel from the cathode to the plate becomes comparable to the time of one cycle of a carrier signal at VHF and UHF ranges.

At these high frequencies, the alternations or reversals of signal input voltage polarity, e_g of Figure 3, become so rapid that maximum voltage, e_g, occurs a short period of time before Q_g maximum is produced on the grid by the electron travel effect. This Q_g delay is caused by the delay in the movement of the electrons from the cathode toward the grid and beyond it due to transit time effect. Thus the Q_g curve of Figure 3 would actually shift to the right to show a time delay.

This phase shift condition will cause the grid displacement current, i_d, to appear less than 90° to the original signal, e_g, which is in a direction toward being in phase with e_g. Such a relationship approaches a resistive condition, and has the same effect as though a resistor were placed from cathode to grid. This shunting effect lowers the circuit Q affecting the gain of a tuner.

Inductive Effects

At high frequencies, even extremely short straight leads and connections in the television circuits exhibit an effective quantity of inductance in the stage or stages to which they are common. Thus, they must always be considered as important reactive components in the television circuits.

Composed of lengths of wire, the internal leads going to the tube elements from the socket pins contain an inductive component, and therefore, the tube may be represented by the equivalent circuit shown in Figure 4, where the small inductors in series with the elements represent the lead inductances. This adds to any external lead inductance and figures effectively in tuning, etc., in any high frequency circuits.

This lead inductance often adds to the difficulties of VHF and UHF amplification in another electron tube property which is caused by the inductance of the cathode lead. This lead is common to both the cathode and grid circuits and the induced voltage developed across it by the high frequency plate current causes a small component of displacement current, i_d, by feedback process, that is exactly in phase with the grid voltage. This in-phase displacement current, i_d, with the signal, e_g, provides another source of shunting effect or conductance which further decreases the total input resistance of the tube, thus lowering circuit Q some more.

Noise

In electron tube circuits the random movement of electrons in the conductors and tubes, generates "noise" which interferes with the signals. All conductors contain free electrons that are in continuous random motion. At any instant, it may be expected that more electrons are moving in one direction than in another, with the result that a voltage will be developed between the ends of the conductor.

This voltage varies in a random manner and thus represents noise energy distributed from the very lowest to the very highest frequencies. Since the motion of the electrons results from thermal action, the name THERMAL-AGITATION NOISE has been given to this effect. Because the magnitude of the noise voltage depends upon the resistance across which it is generated, sometimes it is called RESISTANCE NOISE.

Random noise similar in character to that produced in a resistor is generated in an electron tube as a result of irregularities in the electron flow. Although tube noise may be divided into several classes, those that must be considered in radio and television receivers are SHOT-EFFECT and current PARTITION noises.

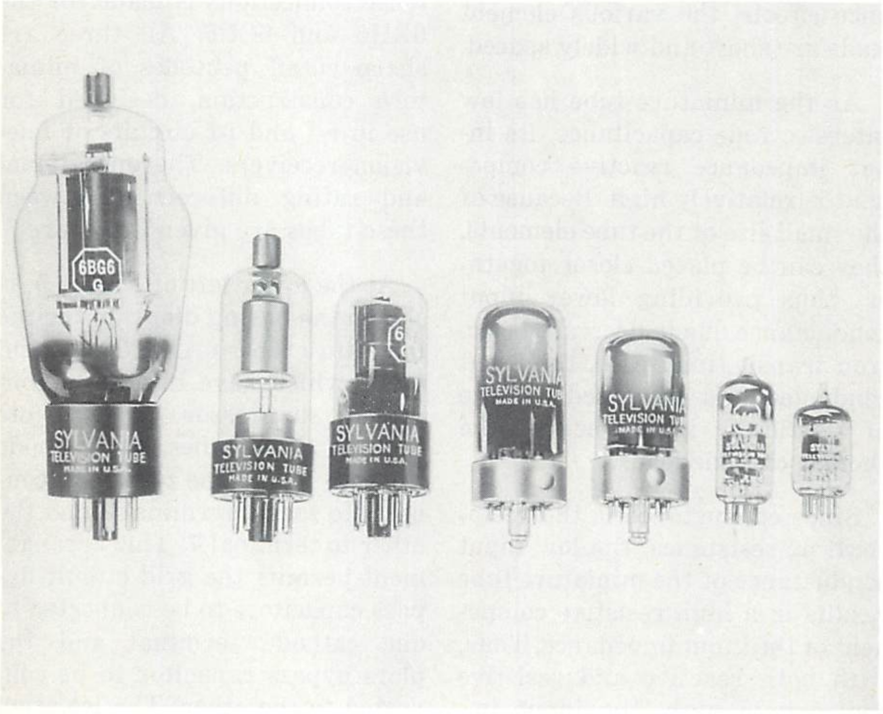
Shot-effect noises are produced as a result of random variations in the plate current due to the fact that the electrons tend to leave the cathode in groups or bunches at random frequencies. These plate current variations cause random plate voltage variations and thus "noise" is produced in the plate circuit.

Current partition noises arise from the chance variation in the division of current between two or more positive electrodes such as in a pentode type tube. The plate and screen grid each receive a portion of the total tube current. At any instant, more or fewer than normal electrons will strike the screen grid and thus cause variations in the momentary total plate current and voltage. Because of this random variation in the division of current between the screen grid and plate, noise is again the result in the plate output circuit. THIS NOISE DOES NOT OCCUR IN A TRIODE BECAUSE THERE IS ONLY ONE POSITIVE ELECTRODE.

In the receiver r-f section, high stage gain is desirable since the more the signal is amplified before noise from the following stages is added, the higher is the over-all ratio of signal-to-noise. This important stage gain is directly proportional to the plate load impedance, to the amplification factor (mu) of triode tubes, and the transconductance (g_m) of pentode tubes, and is inversely proportional to the total capacitance shunting the circuit. Therefore, to provide high stage gain, an amplifier tube should have high mu or g_m and low capacitance between its elements and between the element leads.

High Frequency Tubes

Miniature tubes have been developed for use in television circuits and similar equipment operating at high frequencies because they have a particularly efficient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Various types and sizes of tubes used in television receivers. At the right are the miniature tubes of the kind used in the television tuner unit. The pentode, 6AG5, second from the right is often used as the r-f amplifier in a tuner.

Courtesy Sylvania Electric Products Co.

cathode, close spacing between control grid and cathode, and physically small tube elements. Because of the more efficient cathode, adequate plate current is obtained in spite of the small size of the tube elements. The close grid-cathode spacing gives the grid greater control over the space charge, and results in relatively high values of amplification factor and transconductance. The small physical size of the elements results in lower interelectrode capacitance and, to decrease the total tube capacitance and inductance effects, the various element leads are short and widely spaced.

As the miniature tube has low interelectrode capacitance, its input impedance reactive component is relatively high. Because of the small size of the tube elements, they can be placed closer together, thus providing lower input conductance due to decreased electron transit time. Also, the input conductance is decreased because of the lower inductance of the shorter cathode leads.

Since conductance is the reciprocal of resistance, the low input conductance of the miniature tube results in a high resistive component of the input impedance. Thus, with both reactive and resistive components high, the input impedance of the miniature tube has less shunting effect on the plate load impedance of the preceding stage and thus provides a condition for higher stage gain.

Shown in Figure 5, are the RETMA Standard socket connection diagrams of a number of tubes commonly used in television receivers. In the upper left of the Figure, the diagrams for the type 6AU6, 6BH6, and 6CB6 are the same except for the connections to the cathode and the suppressor grid. For the 6AU6, the suppressor grid connects to socket terminal 2 and the cathode to socket terminal 7, while the reverse of these connections is made for the 6BH6 and 6CB6. All three are sharp cutoff pentodes of miniature construction, designed for use in r-f and i-f circuits of television receivers. The operational and rating differences between these tubes are given in Figure 6.

At the lower left of Figure 5, is shown the basing diagram for the miniature types 6AK5, 6AG5, and 6BC5 which have internally connected suppressor grids. Note that, in these tubes, the cathode has two leads, one of which connects to socket terminal 2 and the other to terminal 7. This arrangement permits the grid circuit bypass capacitors to be connected to one cathode terminal and the plate bypass capacitor to be connected to the other. The isolation of the tube input and output circuits thus obtained prevents degeneration due to lead inductance and permits greater gain per stage. The various ratings of these pentodes mentioned may be compared with those of the broadcast radio r-f amplifier pentode type 6SK7 shown at the bottom of the chart of Figure 6. The total of the input and output capacitance of this tube, 13 $\mu\mu$f, is considerably greater than that of any of the miniature type tubes. Also, the miniature tube tranconductances are all much higher than that of the 6SK7.

The 6C4 is a miniature type triode used as a high frequency oscillator in television receivers, while the miniature type 6J6 may be operated either as an r-f amplifier, a mixer, or a high frequency oscillator. A common cathode is employed for the two sections of this tube, and when the grids are operated in push-pull and the plates in parallel, it performs satisfactorily as a mixer at frequencies as high as 800 mc. Figure 6 shows the 6J6 to have an extremely low output capacitance of 0.4 $\mu\mu$f.

The 7F8 and the 12AT7, 12AU7, and 6BQ7 are dual triodes with separate cathodes for each section, the 7F8 being of the larger glass lock-in type tube while the rest are of the miniature type. The 7F8 is used as an amplifier or as a high frequency oscillator. The duo triode type such as the 12AT7 or 12AU7 may be employed as an r-f amplifier, mixer, or oscillator and has a miniature 9 pin base with base pin No. 9 connected to the center of the heater so that the tube may be used in either a parallel or a series type heater circuit. The 6BQ7 does not have the heater center tap since pin 9 is used for an internal shield. This tube was designed for the cathode driven grounded grid amplifiers found in the cascode circuit described later in this lesson.

Although pentode type tubes are employed as r-f amplifiers in broadcast radio receivers, either pentode or triode r-f amplifier tubes may be found in r-f stages of television receivers. The principal advantages of a pentode are higher voltage gain and prevention of oscillation due to the shielding effect of the screen grid. However, at the high frequencies of the television carriers, and because of the wide bandpass required, the pentode amplifier in a television receiver has considerably lower voltage gain than the r-f amplifier in the broadcast radio receiver.

Therefore, because the noise generated in a triode tube is considerably less than that generated in a pentode tube, triodes are used frequently in the r-f stages of television receivers. However, to prevent oscillation in a triode r-f amplifier circuit, neutralization with external capacitance may have to be employed, but this is relatively unimportant when the improvement of the signal-to-noise ratio obtained in this manner is considered.

Due to its low interelectrode capacitances and small lead inductances, this, and similar 9-pin miniature twin triodes, are often used in a television tuner for the cascode r-f amplifier circuit.

Courtesy General Electric Co.

BANDWIDTH

Before taking up the details of the television receiver r-f section, the operation of tuned circuits is reviewed briefly. In Figure 7, capacitor C is connected in parallel with the series arrangement of L and R. Actually R is not a separate unit but represents the resistance of the wire with which the coil is wound. The impedance of this circuit at a frequency, is equal to:

$$Z = X_c \sqrt{\frac{R^2 + X_L^2}{R^2 + (X_L - X_c)^2}}$$

where:

Z = impedance at any frequency f

$X_c = 1/(2\pi fC)$

$X_L = 2\pi fL$

R = resistance of the coil.

At the resonant frequency, $X_c = X_L$ and, if R is very small, the equation reduces to:

$$Z_r = \frac{L}{CR}$$

where:

Z_r = impedance at the resonant frequency

L = inductance in henrys

C = capacitance in farads

R = resistance in ohms.

A number of conclusions may be drawn from this equation: THE IMPEDANCE OF THE TUNED CIRCUIT IS DIRECTLY PROPORTIONAL TO THE INDUCTANCE AND INVERSELY PROPORTIONAL TO THE CAPACITANCE AND SERIES RESISTANCE; to obtain a large impedance with a given resistance, the inductance should be large and the capacitance small. With the voltage directly proportional to the impedance across which it is produced, a tuned circuit with a large inductance develops a higher voltage than one with a large capacitance.

Selectivity is a measure of the ability of a tuned circuit to discriminate between signals of different frequencies and may be expressed in terms of circuit quality or Q. With a large Q, the response curve is relatively sharp, the selectivity is greater, and the voltage that is developed across the circuit is large. On the other hand, with a low Q, the response curve is broad, the selectivity is poor, and the voltage developed across the circuit is small. Electrically speaking, circuit Q is the ratio of the total energy in the circuit to that which is dissipated and is an important factor because the dissipated energy must be re-supplied by the source. Mathematically, the Q is equal to the inductive reactance, at resonance, divided by the entire series circuit resistance:

$$Q = \frac{X_L}{R} = \frac{2\pi f_r L}{R}$$

where:

f_r = resonant frequency in cycles per second

L = inductance in henrys

R = series resistance in ohms

Since they are required to pass a 6 mc band of frequencies for each channel, the tuned circuits of the television receiver RF section must have wide band characteristics. Therefore, a relatively lower Q as compared with narrow band circuits. In the case of the higher frequency television carriers, the natural Q of the tuned circuit is sufficiently low, because of all the capacitance factors reducing the L/C ratio. However, for the lower frequency television carriers it is sometimes necessary to reduce the Q of the tuned circuits.

One method of obtaining the required lower Q tuning circuits is to increase the series resistance in such a way that the selectivity is reduced. By connecting an actual resistor in series with the coil, like R in Figure 7, the X_L to R ratio can be reduced and the Q lowered, but when this is done, the selectivity curve of the circuit, although broadened, becomes unsymmetrical, with greater response at one edge of the band than at the other.

However, by connecting the resistor in parallel with the tuned circuit, as in Figure 8, the selectivity of the circuit is broadened symmetrically, with a bandwidth inversely proportional to this shunting resistance. Thus, the lower the value of the resistor, the more the shunting action. This lowers circuit Q and broadens the circuit bandwidth.

This parallel resistance is the maximum impedance that the tuned circuit can have under any condition. Hence, to obtain a larger voltage across a tuned circuit, R must be larger, along with a larger L/C ratio. Large values of X_L are obtained by the use of a large inductance and a small capacitance in a tuned circuit.

The 6×8 is a 9-pin miniature triode-pentode. The triode section is the local oscillator, while the pentode section serves as the mixer. This tube is often used in the cascode-circuit tuner.
Courtesy Sylvania Electric Products Co.

In practice, the minimum capacitance in tuners is the circuit stray capacitance in parallel with the tube capacitance. These capacitances are often the only ones employed in television circuits, although very small adjustable capacitors may be included for alignment purposes. THE INDUCTANCE IS CHOSEN TO RESONATE WITH THE STRAY AND TUBE CAPACITANCES AT THE DESIRED CHANNEL FREQUENCY, f_r.

If the desired frequency bandwidth, Δf, is large, the ratio $f_r/\Delta f$ must be smaller, thus the required shunt resistor must be of a lower value. With this condition, most of the circuit losses occur in the shunting resistance, R, and the effective Q is:

$$Q_e = \frac{R}{X_L} = \frac{R}{2\pi f_r L}$$

where:

Q_e = the effective Q of a heavily loaded tuned circuit

R = parallel or shunt resistance in ohms

f_r = resonant frequency in cycles per second

L = inductance in henrys.

Notice that THIS EQUATION IS THE RECIPROCAL OF THE STANDARD Q FORMULA. It is the low parallel or shunt resistance that causes this change.

The condition of coupling between coils is another method of obtaining the proper bandwidth. When two coupled resonant circuits are tuned to the same frequency, the resulting behavior depends largely on the degree of coupling. In Figure 9, inductively coupled coils L_1 and L_2 are resonated to the same frequency by capacitors C_1 and C_2. The curves of Figure 9B show the response as the degree of coupling is increased. Starting with the coils widely spaced, the coupling is small and as shown by curve a, the response is small and sharply peaked.

As the coils are brought closer together, the coupling increases and the response curve becomes larger and broader, with steeper sides, until the secondary voltage reaches a maximum. This condition is known as critical coupling and its curve is shown by curve b. A further increase in coupling causes the response to take on a double humped appearance as shown by curve c. As the coupling is increased still further, the response humps become more pronounced and spread farther apart.

This over coupling method of obtaining a response bandwidth sufficiently wide to provide uniform amplification of the two television carriers and their sidebands often is employed in television receiver r-f and i-f circuits.

R-F AMPLIFIERS

Almost all television tuners employ an r-f amplifier before a mixer, since there are several advantages to be gained by using such a stage.

The receiver selectivity is increased by the r-f amplifier tuned circuits. This results in a greater reduction of unwanted signals.

The signal-to-noise ratio is improved. Any noise generated in the first tube receives the same total amplification as the received signal. In general, more noise is produced in a mixer than in an r-f stage. Thus, with a given signal strength at the input, a receiver with an r-f amplifier has a higher signal-to-noise ratio than one without the r-f amplifier.

The r-f stage also serves as a buffer between the local oscillator and the antenna and decreases the possibility of a local oscillator signal leak through to the antenna. Such signals are radiated by the antenna to cause interference with other receivers in the vicinity.

Generally, the sound and picture signals are not separated before the i-f's are obtained. Therefore, it is necessary that the r-f amplifier and mixer tuned circuits have a bandwidth sufficient to pass the complete television channel of 6 mc.

Input Circuits

The television receiver input circuit couples the antenna transmission line to the first tube in the receiver and is designed so that at the receiver antenna terminals a nearly constant impedance is provided for all channels. This stability is necessary in order to match the receiver to the antenna system for all channels. The common input impedances which will be discussed more completely in a later lesson are 300 and 72 ohms.

One of the most simple and commonly used input coupling circuits in television tuners is shown in Figure 10A and consists of a single tuned transformer L_1L_2, the untuned primary of which is connected to the transmission line and the tuned secondary connected to the V_1 grid circuit. Capacitor C_1 represents the total stray and tube input capacitances as well as that of a tuning capacitor, if one is employed, while R_1 provides for proper matching and bandwidth. As in any resonant circuit, L and C tune the circuit to the desired channel.

This input circuit might be a pre-set unit which may be switched into the stage as desired for each channel, or it may be variable for continuous tuning. Circuit switch contact points are marked for application to a rotating turret type tuner.

Referring to Figure 10A, the primary of the input transformer has a grounded centertap to balance the transmission line to ground and cause cancellation of any noise voltages that may be induced on it. Because the two wires of the transmission line are close together, noise signals tend to induce equal voltages in the wires. The resulting currents in each half of the primary are equal and, being applied from opposite ends of the coil, their effects cancel each other so that no noise signal is coupled to the V_1 grid.

On the other hand, the television signal induces an antenna voltage that causes current from one end of the primary to the other, with little or no signal currents leaving at the center tap. Therefore, the grounded primary center tap does not cause any signal cancellation. At this point, it might be well to point out that noise signals which are induced on the antenna itself are not cancelled by grounding the primary center tap. Noise induced on the antenna may be reduced or removed by re-locating the antenna.

In the circuit of 10B, greater gain and bandwidth are obtained without resistance loading by placing the tuned link, L_2C_1, between the input transformer primary, L_1, and secondary, L_3. As explained for Figure 9, when two coupled resonant circuits are tuned to the same frequency, the resulting behavior depends largely on the degree of coupling. The transformer primary, L_1, is connected to the transmission line and is inductively coupled to L_2, the degree of coupling determining the primary impedance. With the L_1 center tap grounded, the transmission line is balanced to ground and all interfering signals that are induced on the line will cancel each other so that none appear at the V_1 grid.

Resonant circuits L_2C_1 and L_3C_2 are tuned to the same frequency and the coupling between them is adjusted until the desired response characteristics are obtained. In practice when this type of input is used, the circuits usually are arranged so that different sets of coils and capacitors are switched into the active position for each channel. The circuit switch contact points are marked.

The circuit of Figure 10C includes a part of another type of input system used in quite a number of modern tuners. The inductances shown, along with the others for the various channels are grouped around a wafer deck switch, similar to a type which is used in a voltmeter.

The total inductance, which always includes lead inductance, between the switch contact and the input grid, as shown here, forms a series resonant circuit with the grid input capacitance indicated as C_1. The circuit is resonant to the channel that is selected by the switching arrangement. If the switch were moved up in the diagram, the resonant frequency would become lower because more inductance is added to the series circuit.

Various types of transmission lines that take the signal from the antenna to the television tuner input circuit. Appearing from left to right are the 300 ohm twin lead, tubular twin lead and shielded twin lead. The line on the right is a 72-ohm coaxial line; notice the center conductor with the outside shield serving as the other conductor.

It is true that the a-c voltage drop across a total series resonant circuit is minimum and the circulating current is maximum but, it is recalled from fundamentals about series resonance, that the a-c voltage across the individual units, of inductance and capacitance, is maximum. Maximum signal voltage for the selected channel, then, appears across the input capacitance C_1, which includes interelectrode capacitance, etc., and thus is applied into the grid circuit of the stage for amplification.

Grounded Grid Circuits

Figure 10D shows a very simple untuned input circuit used in some tuners. Here, a 72 ohm shielded transmission line is used to connect the antenna to the input circuit. At the receiver, the transmission line outer shield is grounded to the chassis and the inner conductor is capacitively coupled to the cathode circuit of a triode type tube V_1, the control grid of which is grounded. Known variously as a grounded grid amplifier, a cathode input amplifier or an inverted amplifier, this arrangement permits a triode type tube to be employed for improved signal-to-noise ratio while removing the necessity for neutralization.

In a conventional triode r-f amplifier circuit, feedback takes place through the grid-plate capacitance and the resulting oscillation may be stopped only by neutralizing the stage, usually by an adjustable, external capacitor. On the other hand, by grounding the grid and applying the signal to the cathode circuit, the capacitive current through the grid-plate capacitance does not enter the input circuit. Thus, feedback is avoided and oscillation does not take place.

With the control grid connected directly to ground and the signal applied between the cathode and ground, the signal variations cause corresponding changes in the grid-cathode potential. This has the same effect as the signal applied to the grid of a conventional amplifier stage. An advantage of the grounded grid amplifier is that its input impedance is very low and usually loads any tuned circuit sufficiently to provide an adequately flat response over a broad band of frequencies.

Because the cathode circuit can not be bypassed to ground, considerable degeneration occurs and the stage has less gain than a conventional stage employing the same tube.

In Figure 10D, the r-f signals are capacitively coupled to the V_1 cathode and are superimposed on the average d-c bias voltage developed across R_1. The instantaneous grid-cathode voltage variations are amplified by the tube, appear in the variable tuned plate circuit which resonates with the shunt capacitance, C_4, and are applied to the mixer grid. The resistance of R_1 and the V_1 operating voltages are so chosen that the V_1 cathode circuit presents a constant impedance of 72 ohms to the transmission line.

With the transmission line outer shield grounded and the inner conductor coupled to the V_1 cathode, the transmission line is unbalanced to ground. However, noise pickup by the transmission line is prevented by the grounded outer shield.

Since all of the voltages induced on the antenna are coupled to the V_1 cathode circuit, interference may be caused by lower frequency signals. To remove these undesired signals, a high-pass r-f filter such as L_1 and C_1 in Figure 10E is employed between the transmission line and the first tube of the tuner.

At the lower frequencies, the inductive reactance of L_1 is comparatively low and provides an easy path to ground for the signals. At the same time, the capacitive reactance of C_1 is comparatively high and effectively blocks the signal from the V_1 cathode. For the high frequency signals in the television bands, the reactance of L_1 is high, the reactance of C_1 is low and the signal passes readily to the V_1 cathode. As shown in Figure 10D, the input of this circuit is unbalanced to ground and is designed to match the impedance of a 72 ohm co-axial transmission line.

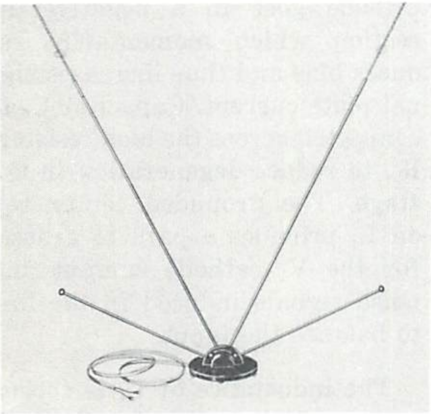
The grounded grid amplifier circuits of Figures 10D and 10E are designed to match the 72 ohm co-axial transmission line and are unbalanced to ground. A method of coupling the twin lead 300 ohm line to some tuners, while retaining the advantages of grounded grid operation of the amplifier tube is shown in Figure 10F.

The transmission line is connected between the grid and ground, and the cathode and ground sections of V_1 so that both serve as signal input elements. The r-f voltage appears across the input inductances and is applied in the grid circuit from grid to the grounded center tap of L_1 or L_2L_3, and in the cathode circuit of V_1 from the bottom end of R_4C_3 to the same grounded center tap, in a type of push-pull input arrangement. As the signal on the grid goes plus to increase signal plate current, the signal on the cathode goes in a negative direction which momentarily reduces bias and thus increases signal plate current. Capacitor C_3 is connected across the bias resistor, R_4, to reduce degeneration in the stage. The grounded center tap on L_1 provides a path to ground for the V_1 cathode current and noise signals induced in the line to balance the input.

The inductance of L_1 is chosen to resonate broadly with the grid and cathode capacitances so as to provide uniform impedance for all the lower television channels. When tuning to the higher channels, switches S_1 and S_2 close automatically to shunt L_2 and L_3 across L_1 so as to reduce the total input inductance for high channel tuning.

In series with the transmission line, capacitors C_1 and C_2 form high-pass filters with L_1, L_2 and L_3 to remove any low frequency interference. To drain static charges from the antenna, resistors R_1 and R_2 are connected in parallel with C_1 and C_2 respectively. Very high resistances are employed so that they have little effect on the operation of the filter.

The circuits of Figures 10D, 10E, and 10F have the transmission line capacitively coupled to the tube input and there is no voltage step-up between the line and tube. By employing a transformer, similar to that of Figure 10A, in the cathode circuit of a grounded grid amplifier, additional output may be obtained from the stage. In Figure 10G, L_3 and L_4 constitute the step-up transformer, C_4 represents the total of the stray and tube capacitances as well as that of any tuning capacitor that may be employed, C_5 is the cathode bypass capacitor and R_3 is the cathode bias resistor. The primary center tap is grounded to balance the input and remove any noise signals that may be induced on the transmission line. The secondary circuit is designed to be broadly resonant so that a uniform impedance is presented to the transmission line.



The television signals from this indoor antenna are carried by a twin-lead transmission line to the input connections on the receiver.
Courtesy American Phenolic Corp.

In operation, the r-f voltage that is developed across L_4 is in series with the d-c bias voltage produced across R_3 and causes instantaneous changes in the V_2 grid-cathode voltage. These changes are amplified by the tube and, appear in the plate circuit, L_5 to be applied to the mixer stage.

The Cascode Circuit

In Figure 11 is a circuit which combines some of the r-f amplifier circuits of Figure 10 into a very practical and highly sensitive r-f amplifier section of a tuner used in many different makes and models of tuners. The circuit shown actually combines the basic circuitry of Figures 10A and 10G.

The entire circuit is built around one duo triode tube, such as a 6BQ7, designated in the diagram as V_1 and V_2. In this arrangement shown, the various coils are indicated as being switched completely in and out of the circuit for the different channels. However, quite a number of different makes of tuners use this **cascode** circuit in a series switching system like the one in Figure 10C.

The input stage of Figure 11 differs from Figure 10A, in that a triode is used for V_1 instead of a pentode. The complete 2 stage circuit is a direct coupled amplifier from V_1 to V_2, where V_2 is actually the plate load for V_1.

The grid of V_2 in Figure 11 is placed at a-c ground potential by the action of C_6. With the grid being thus effectively grounded, V_2 takes on the characteristics of a grounded grid amplifier which, among other things, has the low input impedance as mentioned in an earlier lesson. The V_2 amplified signal output is developed across coil L_5.

The r-f signal from the plate of V_1 appears in the cathode circuit of the V_2 stage. Thus, the low cathode input impedance of V_2 serves as the V_1 output load. Since the coil L_4, across which some of the signal voltage is developed, is also in the cathode circuit of V_2, it serves as part of the signal input load for V_2 along with the interelectrode and stray capacitances present. Actually, L_4, which usually appears only in the high-frequency cascode circuits, works in conjunction with the interelectrode and stray capacitances such as C_i in Figure 11, and provides a series resonant condition from V_1 plate to ground through L_4, C_i and C_6 at the higher channel frequencies in order to maintain good over-all response and relatively constant low output impedance for V_1. The action is similar to that described for Figure 10C.

Since the V_1 plate output impedance working into the V_2 cathode circuit is very low, the V_1 stage has a gain of approximately unity, or one, making interelectrode capacitive effects negligible thus eliminating oscillation. Therefore, neutralizing capacitor, C_3, often is omitted; however, when it is present, it serves only to reduce the slight input capacitive and conductance effects in V_1, thereby improving the Q of the input grid circuit.

Notice that V_1 and V_2 are actually in series from B+ to ground insofar as the cathode to plate d-c path is concerned, with the R_p of V_1 and V_2 serving as a voltage divider. As a result of this direct coupled arrangement, the cathode of V_2 is at about the same d-c potential as the plate of V_1, which is approximately 150 volts. L_4, consisting of only a few turns because of the high frequencies involved, has no practical d-c resistance.

With this high d-c potential at the cathode of V_2, some compensating circuit must be used for proper V_2 grid bias. Therefore, as shown in Figure 11, a positive voltage of 148 volts is applied to the V_2 grid through the R_4, R_5 voltage divider circuit from the 250 volt B+ point marked on the diagram.

C_6 serves as a filter to maintain a constant d-c on the grid for the effective grounded grid amplifier action. Thus, with +150 volts d-c in the V_2 cathode circuit and +148 volts d-c at the V_2 grid, the cathode is 2 volts positive with respect to the grid or, it can be stated, that the V_2 grid is biased 2 volts negatively with respect to the cathode.

The output video and sound carrier signals from V_2 appear across r-f plate coil L_5 and are coupled to L_6 for application to the mixer portion of the tuner assembly.

THE MIXER

As shown in the diagram of Figure 1, the television tuner mixer stage actually receives 3 basic signals: the video r-f, the sound r-f and the local oscillator r-f. As a result of the heterodyning of these three signals, the mixer output contains a relatively large number of frequencies. As is usual in a superhet arrangement, the intermediate frequencies (i-f) are used, while the high frequencies present are rejected by the tuned i-f circuits.

Thus, the superhet television tuner mixer stage converts the high frequencies of the video and sound carriers simultaneously to lower, intermediate frequencies where greater gain, selectivity, and circuit stability are obtained more easily.

The difference frequency between the video carrier and the one local oscillator frequency is the video intermediate frequency, while the difference frequency between the sound carrier and that local oscillator frequency is the sound intermediate frequency.

Since the same local oscillator frequency beats with both carriers which are always 4.5 mc apart, the resulting lower video and sound i-f carriers also are 4.5 mc apart.

Because of several design considerations, the tuner local oscillator tuned frequency is generally operated higher than the two tuned incoming carrier frequencies. A few tuners do tune the local oscillator frequency below the incoming carriers.

Where the applied local oscillator signal is above the original sound and video carrier frequencies, the resulting video and sound i-f signals in the mixer output will appear with the video being 4.5 mc higher in frequency than the sound, although the video carrier was originally lower in frequency.

For example, in the diagram of Figure 12 when the tuner input circuits are tuned to channel 3 the tuner local oscillator in this case operates at 107 mc. Since any i-f signal is the difference in frequency between the local oscillator and the carrier, it is the distance between the oscillator frequency and the carrier frequency which determines the intermediate frequency. Like in a radio receiver, the tuner oscillator always is tuned to maintain the same i-f difference at any selected channel by being ganged with the RF and mixer circuits in a tuning system.

In the arrangement of Figure 12, the greatest frequency distance exists between the oscillator and the video carrier, while a lesser distance, by 4.5 mc, exists between the sound carrier and the oscillator. Thus the highest resulting i-f will be the video, and the lower difference will be the sound.

As indicated in Figure 12, the video carrier frequency for channel 3 is 61.25 mc; thus, with the local oscillator frequency at 107 mc, the video i-f is 107 mc −61.25 mc, or 45.75 mc as shown. The accompanying sound carrier, as indicated, is 65.75 mc; thus, the sound i-f is 107 mc −65.75 mc, or 41.25 mc.

In a large portion of the television receivers, separate tubes or tube sections are used for the mixer and local oscillator, as the single cathode combination tubes that are available generally are not satisfactory. These tubes do not have high enough conversion gain and do not oscillate readily over the wide range of frequencies that must be covered. Usually the incoming television signals and the oscillator output are applied to the mixer tube control grid, this arrangement providing greater gain and less noise than

This television receiver uses a turret type tuner. The slender inner control knob at the right side of the receiver rotates the turret to the desired channel while the round outer knob is for channel fine tuning.

Courtesy Admiral Corporation

when the oscillator output is applied to some other element inside the tube. Depending on circuit design, either triode or pentode tubes may be used in the mixer stage. Grid leak or cathode bias may be employed, with the mixer operating in practically the same manner as a plate detector.

Input Coupling Circuits

In Figure 13A, the r-f amplifier tube, V_1, is coupled to the mixer tube, V_2, through a single-tuned transformer L_1, L_2, and C_1.

This circuit is tuned to the same frequency as the r-f amplifier input and the tuning or switching considerations for that circuit also will apply to this coupling circuit. As for the input circuit, the bandwidth of the coupling circuit must be sufficiently broad to provide uniform amplification of the two carriers and their sidebands. Generally the circuit losses are sufficient to lower the Q to that necessary for the desired bandwidth, but if not, additional resistance may be connected across the secondary as described for Figure 8.

The gain of an amplifier stage depends largely upon the plate load impedance and, with the primary L_1, untuned, the V_1 load impedance is comparatively small. To increase the load impedance, a double-tuned transformer may be used as shown in Figure 13B. Here both the pricary and secondary are tuned to the same frequency, the load impedance is higher than in Figure 13A and a higher gain may be obtained from the r-f amplifier stage.

Given by $Z_r = L/CR$, the LC circuit resonant frequency impedance is directly proportional to the inductance and inversely proportional to the capacitance and resistance. Therefore, for high gain, the tuned circuit inductance to capacitance ratio should be large. To obtain a large L to C ratio, many television r-f coupling circuits are designed so that the inductance is resonated by the interelectrode capacitance of the tubes, the circuit stray capacitances, and the distributed capacitance of the coil. A small adjustable capacitor may be included for slight adjustment of the circuit resonant frequency. This total constitutes the absolute minimum capacitance shunting the tuned circuits.

Thus, in Figure 13B, C_1 may represent the V_1 output capacitance plus the stray capacitance in the V_1 plate circuit plus the distributed capacitance of L_1, while C_2 may represent the V_2 input capacitance, the stray in the V_2 grid circuit and the distributed capacitance of L_2. Because of the importance of stray capacitance as well as stray inductive coupling in such circuits, all parts should be positioned carefully and leads kept short and direct.

To obtain sufficient bandwidth, the coupling between primary L_1 and secondary L_2 may be increased beyond the critical point until the response is double-humped as shown by curve c of Figure 9.

An important modification of the circuit in Figure 13B is shown in Figure 13C. Here L_1 and L_2 function as a double-tuned transformer, the primary and secondary of which are tuned by C_o and C_1. In series between the V_1 plate and L_1, capacitor C_b isolates L_1 from the V_1 d-c plate voltage, thus removing the high voltage from any coil switching arrangement that might be employed. Figure 13C shows series coil switching. V_1 plate voltage is applied through R. At the radio frequencies, the reactance of C_b is very low and R is effectively in parallel with the tuned circuit L_1C_o, hence this circuit represents a combination of resistance loading and overcoupling.

Impedance coupling is shown as the method for applying the local oscillator signal to the mixer input circuits in Figure 13; however, a number of tuners use the inductive coupling arrangement of Figure 11 where the local oscillator signal is shown coupled from L_7 to L_6.

The size of the oscillator coupling capacitor, C_c, in Figure 13, usually averages about 1 to 1.5 $\mu\mu$fd. This coupling capacitance may take the form of a physical capacitor, or alternatively, a length of wire connected to the oscillator coil may be wound once or twice around the grid lead of the mixer, the capacity being that of two conductors with their insulation as a dielectric.

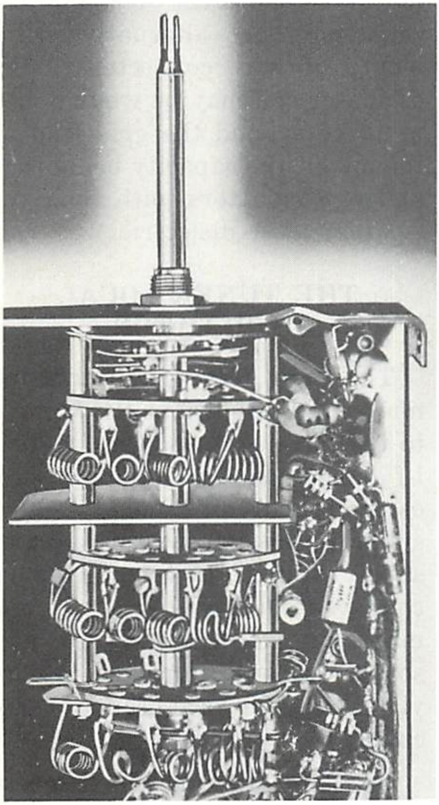
THE TUNER LOCAL OSCILLATOR

The high frequency oscillator must supply sufficient RF voltage to the mixer to produce a strong i-f output and, in addition, the oscillator circuit should be as stable as possible with respect to supply voltage and temperature changes. The triode type tube makes an excellent oscillator and so frequently is employed in television receiver local oscillator circuits.

Oscillator tuning is extremely critical, particularly in any dual channel i-f arrangement because the accompanying sound i-f must fall within the pass band of the sound i-f amplifier, and the associated and adjacent channel sound i-f must fall accurately on the rejection frequencies of any trap circuits that may be employed in the video i-f amplifier.

As a rule this sound i-f channel can pass the sound signal within the range of plus or minus 100 kc.

In the intercarrier receiver where the fixed 4.5 mc beat difference becomes the final sound i-f for the sound detector, oscillator drift is not as critical. Regardless of how much oscillator drift there is, the mixer output i-f carriers always stay 4.5 mc apart to produce the 4.5 mc sound i-f.



A wafer deck switch type tuner. All of the coils are permanently mounted. A gauged switching arrangement places more or less of the coils in series for tuning in the desired channel.

Courtesy Motorola Inc.

Basic Circuits

Because of its stability and its application to interelectrode capacitances and lead inductance effects, the Colpitts type oscillator is one of the common local oscillators used in television tuners.

In Figure 14A is the basic diagram of a shunt-fed Colpitts oscillator as used in some of the tuners. The main feature of the Colpitts oscillator is the feedback arrangement involving a tapped tank capacity rather than the tapped tank coil method of a Hartley.

Capacitance C_1, represents a fixed capacitor plus input capacitance which includes the interelectrode capacitance, C_{gK} and all other grid-circuit capacitive effects previously mentioned. Capacitor C_2, is also paralleled by the total output capacitance C_o, which includes the interelectrode capacitance, C_{pk}. The variable capacitance indicated, peak tunes the received channel. It will be noticed that in all cases of this type oscillator, the grid to plate capacity, C_{gp}, and the coil distributed capacity, C_d, shunt the tank circuit and are used as frequency determining factors.

Coil L_7 can be compared with coil L_7 in Figure 11. In this particular case, individual coils are switched in, and fix tuned for a channel. The oscillator signal is inductively coupled into the mixer load coil in the arrangement of Figure 11.

An equivalent circuit of the Colpitts oscillator sometimes called the **ultraudion,** is shown in a basic arrangement in Figure 14B. This modified Colpitts circuit is extensively used with different tuning systems in many television tuners. Again C_{gp} parallels the tank circuit.

The main difference between this circuit and the basic Colpitts lies in the fact that feedback takes place through the tube interelectrode capacitance. The tapped capacitance now is fixed, which in this case is the interelectrode capacitance of C_{pk} and C_{gK}. Any fine tuning usually exists in a separate physically placed L or C across the total tank circuit indicated by L_1C_1.

Occasionally, a small capacity is added externally from grid to cathode, which improves the tapped capacitance feedback ratio and provides for a stronger oscillator output to the mixer grid.

In Figure 14C is another Colpitts variation for an **ultraudion** oscillator. A different arrangement of channel selection is again shown so that a general familiarization of various types of selection methods is obtained. Actually, any of these circuits can employ any one type of channel selection system.

Figure 14C has its equivalent circuit shown in Figure 14D. Capacitor C_4 does not appear here, since it effectively places the plate at a-c ground potential. The inductance L_k maintains the cathode at above a-c ground potential; thus, the interelectrode capacitance C_{pk} is again an effective part of this oscillator circuit. Except for the change in ground reference and a slight change in the grid-leak bias method of R_1C_3, the oscillator is identical in operation to Figure 14B.

These oscillator circuits then, with a few variations, along with the other tuner circuits described in this lesson form the basis for almost all of the VHF tuner arrangements and many of the UHF tuner methods. This lesson thus serves as background to understanding the complete television tuner circuits and assemblies.

The next lesson, therefore, will concern the various kinds of VHF tuners actually employed in present day television receivers. Not only are the circuits described and diagrammed but an explanation of some of the mechanical assemblies and the problems they present are included in that lesson.

IMPORTANT DEFINITIONS

CASCODE—[kas KOHD]—A two stage direct coupled r-f tuner amplifier circuit developed for television receivers.

HOT INPUT CAPACITANCE—An effect which takes place only during an applied signal, and is produced by the changing movement of the electrons from cathode to plate. It is the result of these electrons repelling the electrons on the grid out into the external grid circuit. This actually becomes a 90° leading electron displacement current for a capacitive effect.

HOT INPUT CONDUCTANCE—An input signal shunting effect which becomes more evident at higher and higher r-f. It is caused by tube transit time conditions which shifts the displacement current to less than 90° for a shunting resistive effect.

TRANSIT TIME—The time it takes an electron to travel between elements inside an electronic tube.

ULTRAUDION—[uhl TRAW de un]—A high frequency oscillator of the Colpitts type, where the tapped capacitances are fixed and usually are only the interelectrode capacitances of the oscillator tube.

STUDENT NOTES

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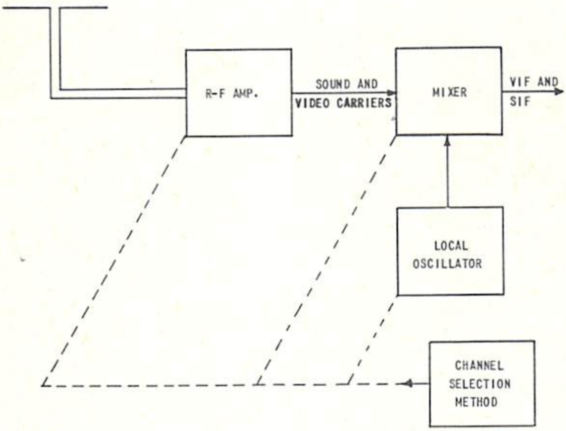


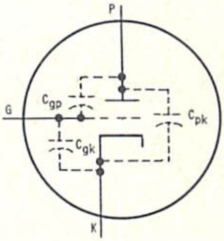


FIGURE 2

FIGURE 1

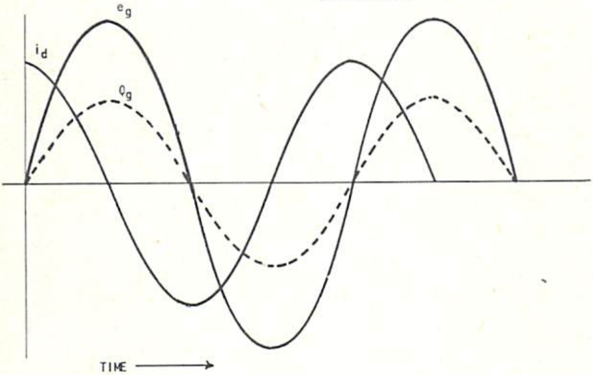


FIGURE 3

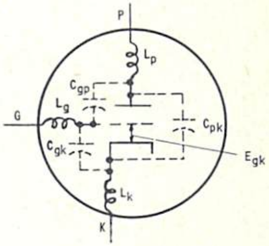


FIGURE 4

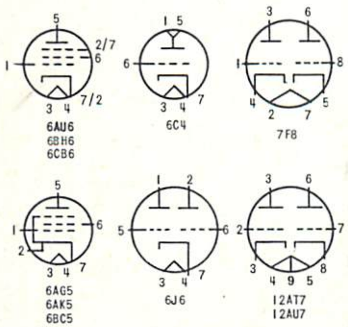


FIGURE 5

TUBE TYPE	INTERELECTRODE CAPACITANCES IN $\mu\mu f$ GRID-PLATE	INPUT	OUTPUT	G_m μMHOS	μ
6AU6	.0035	5.5	5.0	5200	5200
6BH6	.0035	5.4	4.4	4600	6440
6CB6	.0200	6.3	1.9	6200	3700
6AG5	.0250	6.5	1.8	5100	2550
6AK5	.0200	4.0	2.8	5100	3500
6BC5	.0250	6.5	1.8	6100	3050
6C4	1.4	1.8	2.5	3100	19.5
6J6	1.6	2.2	0.4	5300	38
7F8	1.2	2.8	1.4	3300	48
12AT7	1.45	2.5	0.45	6600	62
12AU7	1.5	1.6	0.40	3100	20
6BQ7	1.15	2.85	1.35	6000	35
6SK7	.003	6.0	7.0	2350	282

FIGURE 6

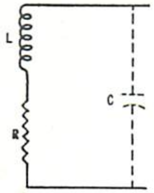


FIGURE 7

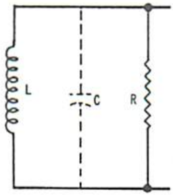
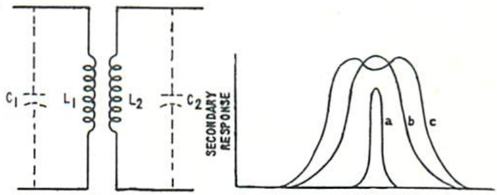


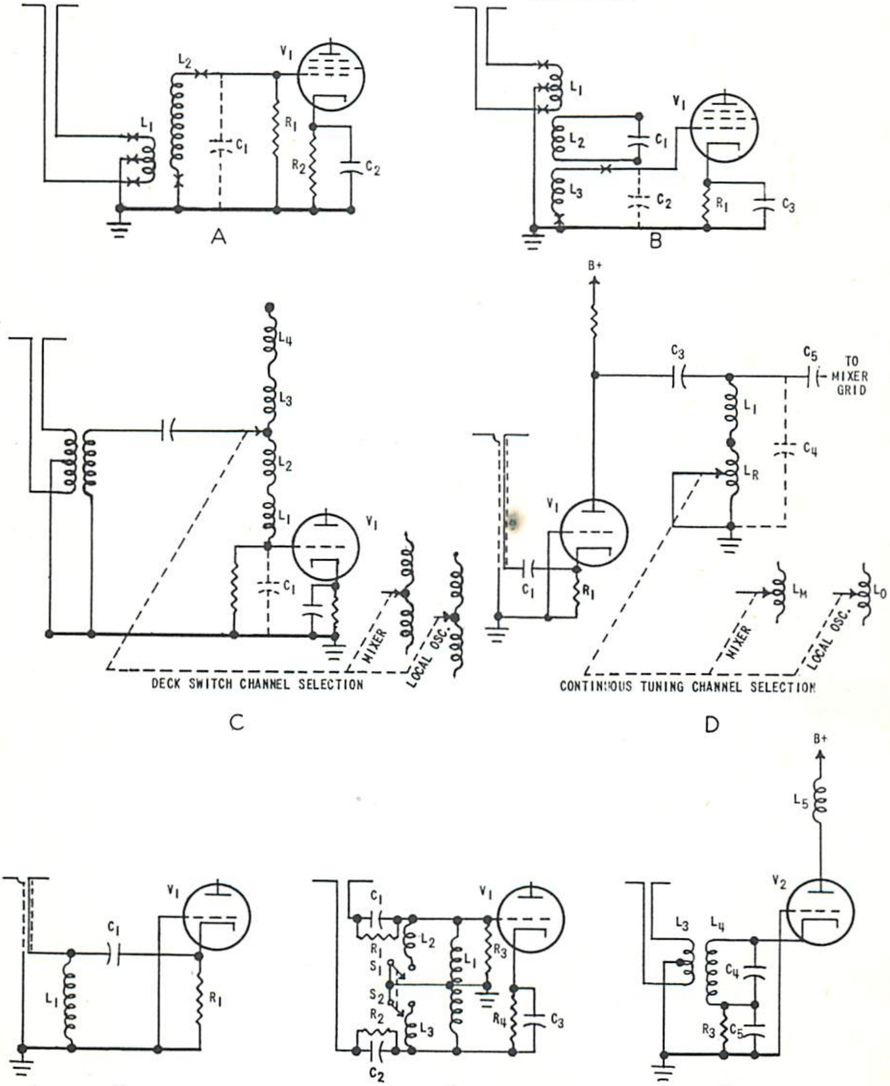
FIGURE 8



A

FIGURE 9

B



A

B

C

D

E

F

G

FIGURE 10

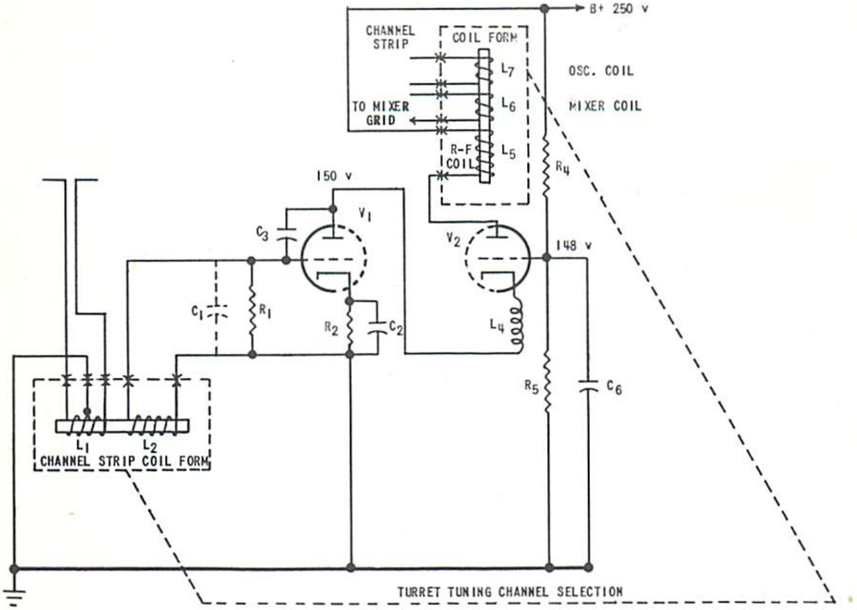


FIGURE 11

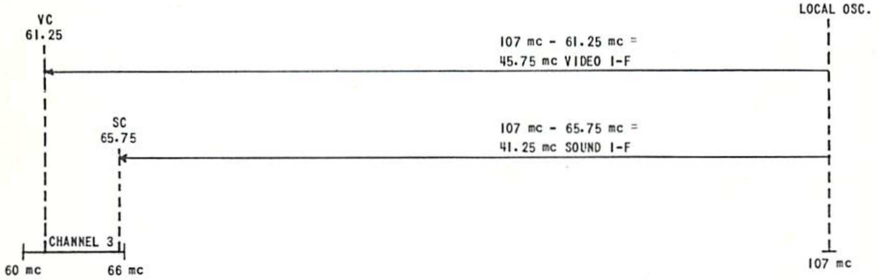


FIGURE 12

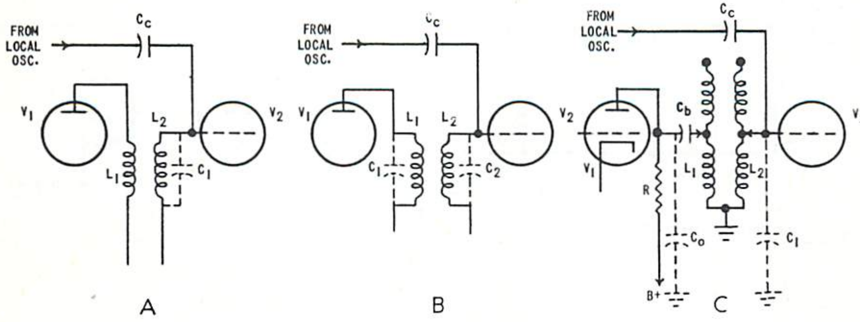


FIGURE 13

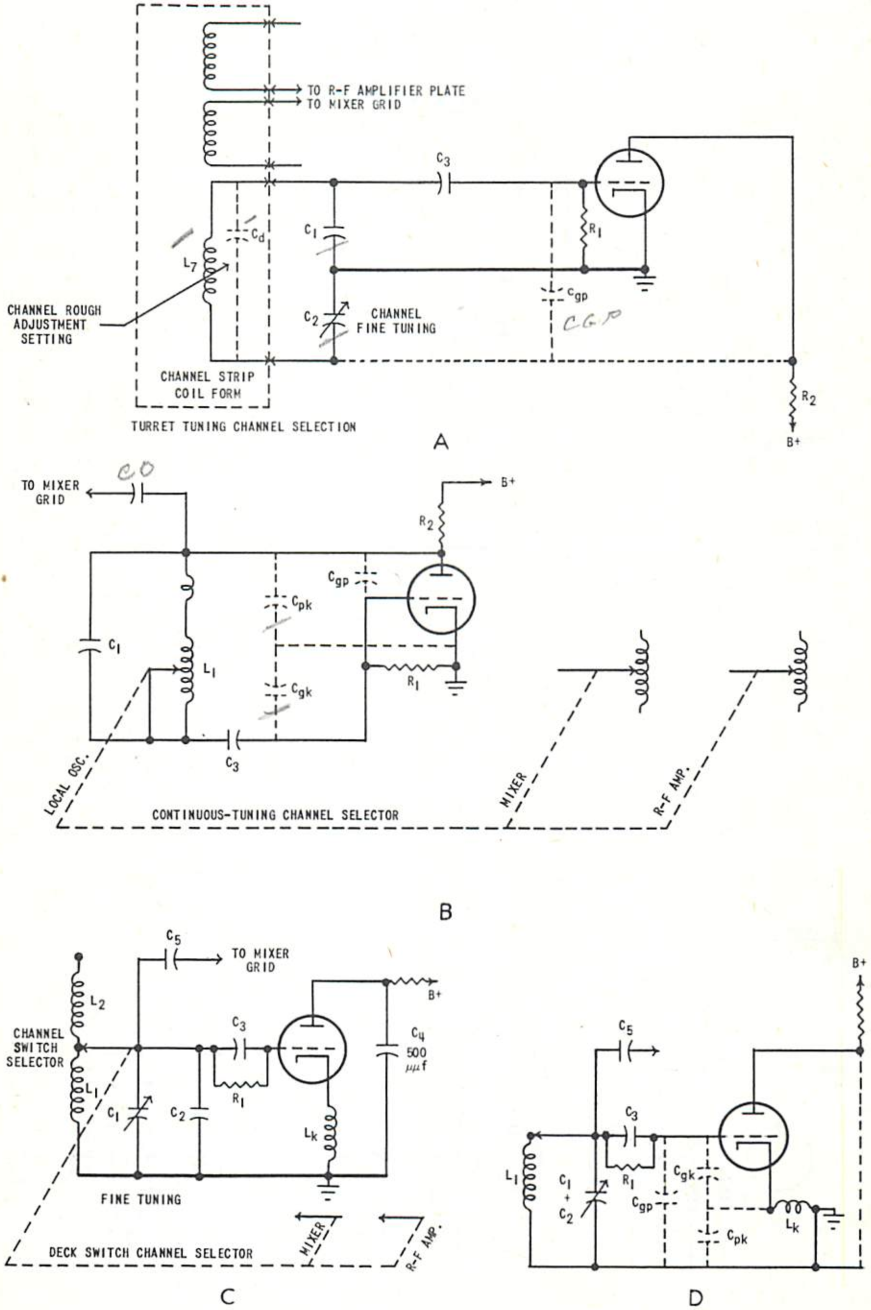

TO R-F AMPLIFIER PLATE
TO MIXER GRID
C_3
C_d
L_7
C_1
R_1
CHANNEL ROUGH ADJUSTMENT SETTING
C_2
CHANNEL FINE TUNING
C_{gp}
CGP
CHANNEL STRIP COIL FORM
R_2
B+
TURRET TUNING CHANNEL SELECTION
A
CO
TO MIXER GRID
B+
R_2
C_{gp}
C_{pk}
C_1
L_1
R_1
C_{gk}
C_3
LOCAL OSC.
MIXER
R-F AMP.
CONTINUOUS-TUNING CHANNEL SELECTOR
B
C_5
TO MIXER GRID
B+
L_2
CHANNEL SWITCH SELECTOR
C_3
C_4
500 $\mu\mu f$
L_1
R_1
C_1
C_2
L_k
FINE TUNING
MIXER
R-F AMP.
DECK SWITCH CHANNEL SELECTOR
C
B+
C_5
C_3
L_1
C_1 + C_2
R_1
C_{gk}
C_{gp}
C_{pk}
L_k
D

FIGURE 14

FROM OUR *Director's* NOTEBOOK

OPPORTUNITY

"They do me wrong who say I come no more
When once I knock and fail to find you in;
For every day I stand outside your door,
And bid you wake, and rise to fight and win."

"Wail not for precious chances passed away,
Weep not for golden ages on the wane;
Each night I burn the records of the day;
At sunrise every soul is born again."

Yours for success,

W. C. DeVry
DIRECTOR

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